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Pilot studies were conducted to begin to explore the influence of moving auditory environments on standing balance control. The pilot study showed that within the paradigm presented, auditory information had little, if any effect on postural sway.

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FINAL TECHNICAL REPORT

AASERT: Influence of Multisensory Stimulation on Ocular Motor Performance
Grant No. F49620-95-1-0385

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July 18, 2000

Objectives:

The objectives of this project were to provide a training environment for two graduate students per year in the area of human spatial orientation and disorientation. Each of the two graduate students were to have a project designed to augment ongoing research. The work to be performed was to allow independent thinking and the development of research skills.

Personnel Supported:

Two graduate students were funded for each of three years. The dates of funding, names and backgrounds of these individuals are as follows:

September 1995 - August 1996

Mr. John B. Candee: Holds a B.S. in E.E. from the University of Pittsburgh. He was enrolled as a full-time graduate student in the Computer Science Department. With very good academic standing, his goal was to complete the M.S. degree, on the way to pursuing the PhD. He is American.

Mr. Russell P. Lentini: Holds a B.S. in C.S. from Millersville University of Pennsylvania. He was a full-time graduate student in the Computer Science Department, with very good academic standing, working on completing the M.S. with interest in also getting a PhD. He is American.

September 1996 - August 1997

Mr. Craig Campbell: Holds a B.A. in English Literature from Denison University. He was a full-time graduate student in the School of Information Sciences. With very good academic standing, he was working on completing the M.S. in Information Science. He is American.

Mr. Jason Thiel: Holds a B.S. in Computer Science from Westminster College. He was enrolled as a full-time graduate student in the Computer Science Department. With very good academic standing, his goal was to complete the M.S. degree. His is American.

September 1997 - August 1998

Mr. Daniel Latt: Holds a B.S. in Mechanical Engineering from the University of California, San Diego. He was enrolled as a full-time graduate student in the Department of Bioengineering. With very good academic standing, his goal was to complete an MD/PhD in Orthopaedic Biomechanics. He is Canadian.

Mr. Robert P. Santos: Holds a B.S. in Electrical Engineering from Bucknell University. He was enrolled as a full-time graduate student in the Department of Bioengineering. With very good academic standing, his immediate goal was to complete the M.S. degree, and then a PhD. He is American.

Accomplishments/New Findings:

The first specific aim of this project, when originated in 1995, was to investigate the role of the auditory sensory information in spatial orientation and disorientation. The two students employed in the first year focused on this problem by working with a 3-dimensional sound system and developing software to produce sounds in any specified global coordinate system location. The students then produced sounds that could move in the environment in any prescribed trajectory. Once this was

accomplished, pilot studies were conducted to begin to explore the influence of moving auditory environments on standing balance control. Sounds of varying frequency content were moved in the environment while subjects stood with eyes closed on a force platform. The force platform measured center of pressure, which correlates with the sway of the subject. Sounds were moved in the sagittal and frontal planes sinusoidally, as well as in a circular motion in the transverse plane. Subjects were asked to stand as still as possible during the presentation of the auditory stimuli. This pilot study showed that, within the paradigm presented, auditory information had little, if any effect on postural sway. This was particularly true for pure tones. There were some motions correlated with the auditory stimuli for some broad-band auditory signals, however these were intermittent and not definitive. Thus, the accomplishment in this first year was to: 1) develop a system to provide auditory signals from any position in space and provide virtual motions of this auditory signal around the subject, 2) conduct a preliminary study determining the effect of these signals on postural sway, and 3) determine that this auditory signal under this paradigm had minimal effect on postural sway.

This first year enabled the students to obtain valuable training in the programming of 3-D sound projection systems, which enhanced their computer science degree experience. In addition, the students read a number of papers and gained a greater understanding of spatial orientation.

In the second year of the project, two new students were recruited. Mr. Jason Thiel continued the work initiated in Year 1, investigating further the role of auditory information in postural control. He developed more complex auditory signals for testing in postural control paradigms. These more complex signals included different types of harmonic tones, broad-band noise, and music. In a pilot study he showed that again, more complex broad-band auditory signals had greater effects. However, the postural response to all of these auditory signals was moderate at best. This finding reinforced our previous finding that auditory information was minimally effective in disrupting postural control and postural sway. We, therefore, at this point, determined that auditory information was of minimal use in our further studies of spatial orientation and discontinued this aspect of the line of research.

Mr. Craig Campbell was supported in the second year to investigate the role of vestibular information in postural control and spatial orientation through the use of galvanic vestibular stimulation. In this protocol, small electrical currents were provided trans-cutaneously to the vestibular nerve while postural sway was monitored using force plates and other motion detection systems. Mr. Campbell developed software to provide a stimulus to the vestibular system through an optically-isolated current generator. These stimuli could be provided in various wave forms, the first of which were sinusoids. Mr. Campbell's study of human subjects showed complex postural responses to galvanic stimulation. He then combined the vestibular stimulation with a simple virtual reality visual stimulation to investigate the effects of coupling the two stimuli. In this study, Mr. Campbell found strong coupling effects between vestibular and visual artificial stimulation. However, there were some complex interactions, particularly the phase relationships that needed to be further explored.

Both students benefited greatly from this experience. Mr. Thiel extended his knowledge of controlling and programming auditory generating equipment and also gained a greater understanding of spatial orientation. Mr. Campbell also acquired a greater knowledge of postural control and vestibular function and spatial orientation. Additionally, he acquired an understanding of how to stimulate the vestibular system and generate simultaneous virtual reality scenes. Mr. Campbell then went on after this experience and started a company to develop a product in this general area of vestibular stimulation with virtual reality. He obtained venture capital and is currently president of this corporation.

In the third year of this AASERT award, Mr. Daniel Latt and Mr. Robert Santos were funded. Mr. Latt continued with the galvanic stimulation work, focusing on the utility of galvanic stimulation and

understanding the human spatial orientation system. He developed protocols for measuring postural sway during galvanic vestibular stimulation to understand this system.

Mr. Santos developed mathematical control models for the spatial orientation system. These models were an extension of previous masters' thesis work performed at the University of Pittsburgh in light of some of the vestibular stimulation work and visual orientation work done by other students and faculty. In particular, the models were designed to allow simulations that could mimic the time-varying or adaptive properties of the postural control system seen in the previous experiments.

Both students benefited greatly from this experience. Mr. Latt went on to continue in the area of orientation and vestibular stimulation, recently completing his Ph.D. in Bioengineering on this topic. He is now returning to medical school to complete the M.D. portion of his M.D./Ph.D. Mr. Santos gained from this experience an appreciation for control modeling of biologic systems. He has subsequently graduated with an MS in Bioengineering and is currently working in electrical engineering in controls.

Publications:

There were no publications that were generated directly from the work of these students in these projects. However, these projects generated pilot data that were essential to our understanding of where to begin further research that did generate publications. The following are publications from research that was engendered and influenced by the projects accomplished in this AASERT grant.

Peer-Reviewed Publications:

Borger LL, Whitney S, Redfern MS, Furman JM: The influence of dynamic visual environments on postural sway in the elderly. *J Vestib Res* 9(3):197-205, 1999.

Ardic F, Latt LD, Redfern MS: Paraspinal muscle response to electrical vestibular stimulation. *Acta Otolaryngologica* (Stockh) 120:39-46, 2000.

Proceedings:

Loughlin PJ, Redfern MS, Furman JM: Time-frequency analysis of visually-induced postural sway of healthy young and elderly subjects. Proceedings of the 3rd International Workshop on Biosignal Interpretation, Chicago, IL, June 12-14, 1999.

Latt LD, Redfern MS: The direction of the postural sway response to sinusoidal galvanic vestibular stimulation. Proceedings of the 1999 American Society for Biomechanics Meeting, Pittsburgh, PA, October 1999.

Abstracts:

Latt LD, Redfern MS, Cass SP: The postural sway response to sinusoidal galvanic vestibular stimulation in humans. Association for Research in Otolaryngology Mid-Winter Research Meeting, February 1998.

Redfern MS, Loughlin PJ, Furman JM: Modeling time-varying properties of sway. International Society for Posture and Gait Symposium, Waterloo, Ontario, Canada, July 1999.

Latt LD, Redfern MS: The response of the paraspinal muscles to electrical vestibular stimulation. International Society for Posture and Gait Symposium, Waterloo, Ontario, Canada, July 1999.

Redfern MS, Loughlin PJ, Furman JM: Time-varying postural response to visual perturbation in aging and vestibular disorders. Association for Research in Otolaryngology Mid-Winter Research Meeting, February 2000.

New Discoveries, Inventions and Patent Disclosures:

No inventions or patent disclosures directly resulted from this grant. However, we have now developed a virtual reality system within the Center for Balance Disorders to investigate spatial orientation. Information gained in this AASERT project has been used in the development of our new virtual reality system.

Honors and Awards:

None.